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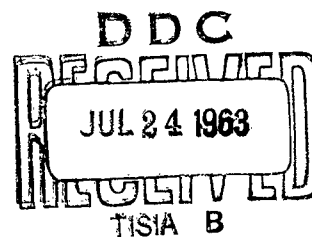
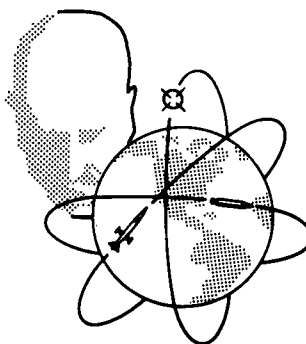
HUMAN FACTORS CONSIDERATIONS IN THE DESIGN OF A TRAINING
AND PROFICIENCY FACILITY FOR THE AN/TSQ-47 SYSTEM

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-63-328

APRIL 1963

Frederick H. Kresse

482L/431L SYSTEMS PROGRAM OFFICE
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L.G. Hanscom Field, Bedford, Massachusetts



(Prepared as Technical Report No. 3 under Contract No. AF 19(628)-439 by HRB-Singer, Inc.
State College, Pennsylvania)

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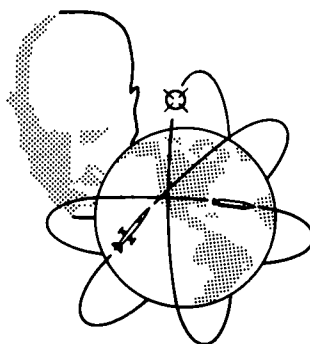
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FOREWORD

This is the third in a series of technical documentary reports resulting from HRB-Singer's Human Factors work on the AN/TSQ-47 Air Traffic Control/Communications System under contract No. AF 19(628)-439. The work was carried out at Ft. Dawes, Winthrop, Mass., under the monitorship of the 431L/482L System Project Office of the Air Force's Electronic Systems Division. This is HRB-Singer report No. 353-R-3.

ABSTRACT

The mobile nature of the Air Force's AN/TSQ-47 Air Traffic Control system calls for periods of peak performance on the part of its air traffic controllers. These periods are separated by sometime prolonged intervals during which controller skill can deteriorate. This report deals with the design of a Training and Proficiency Facility to maintain controller skill between system deployments. Specifically, it formalizes the present conception of the facility, it discusses design considerations that may add to or modify the present conception, and it sets forth recommendations for further effort.

This technical documentary report has been reviewed and is approved.

B. F. GREENE, JR.
Technical Contract Monitor

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SECTION 1

INTRODUCTION

1. Background.

Because of the nature of its mission, the Air Force must be ready and able to operate in all parts of the world. This means that it must be ready to conduct air operations in all climates, under all-weather conditions, and from all types of bases. Many of these bases are not equipped with modern air traffic control, navigation and communications facilities.

In order to provide positive control of aircraft under such varying conditions, the Air Force has developed and is now using a mobile air traffic control system which can be flown into remote areas and used to bring in aircraft. This system is becoming outmoded, however. It is too bulky and awkward for aerial deployment, its electronic components are becoming obsolete, and it lacks communications capacity. For these and other reasons a new mobile system is being developed to provide the Air Force with air traffic control, communications, and navigational aid facilities that are commensurate with its operational needs.

Designated AN/TSQ-47 this new system will consist of 10 major facilities, all packaged in air transportable shelters. Six of these facilities are now being developed by RCA for the 482L/431L System Project Office of the Air Force's Electronic Systems Division. Making up the primary operating portions of the system, these six facilities may be referred to as the basic system. It consists of:

- a. A TACAN navigational facility
- b. A surveillance radar
- c. A precision approach radar
- d. A VFR control tower
- e. A radar approach and control facility (RAPCON)
- f. A communications facility

Four more facilities are to be added to the basic system. One is the ground transport and aircraft loading equipment on which development is presently being initiated. The second, for which specifications are now being formalized, is a mobile runway lighting system to support night and bad weather operations. The other two facilities - a maintenance facility and a training and proficiency facility - are still in the design study phase.

2. Purpose of This Report.

This report deals with the planned Training and Proficiency Facility (TPF). The authority for developing TPF specifications is established by the System Operational Requirement (SOR 194) under which the TSQ-47 system as a whole is being developed. Up to now, however, the concept of a TPF and a plan for developing it have not been formalized. In general, this is what this report is intended to do. More specifically, its purposes are:

a. To formalize the current concept of the TPF so that it may be subjected to examination, discussion, and refinement.

b. To identify and explore some of the major design considerations influencing this refinement process.

c. To set forth recommendations for future efforts.

The sections that follow deal in turn with each of these purposes.

SECTION 2

CURRENT CONCEPT OF THE TRAINING AND PROFICIENCY FACILITY

1. Scope.

This section describes the concept of the TPF as it stands today. The concept is not one that has been set forth by a single person. Instead, it is a composite of the various opinions and views that people have expressed with respect to the planned facility. Discussions concerning the characteristics of the facility, its desirability, the requirements it is meant to fulfill, etc., have been held with Air Force personnel from the 482L/431L SPO; the Operational Applications Laboratory at ESD; Headquarters, Air Force Communications Service, Scott AFB, Missouri; and the 3rd Mobile AFCS Squadron at Tinker AFB, Oklahoma. Throughout, heavy emphasis has been placed on the requirements expressed in the SOR.

In integrating these points of view our own experiences quite naturally affected the interpretations, selections and choices that had to be made, so that this section really presents the TPF concept "as it appears to us." At this stage, however, it is not important how "real" or "true" the concept is. What is most important is that a concept be made explicit. With that accomplished, there is something to work with, to modify and refine.

2. Present Concept of the TPF.

This subsection describes and then discusses the concept of the TPF in terms of the following factors: the functions of the TPF; the trainee population for which it is intended; the place where the training is to be conducted; and the equipment that is anticipated.

a. Functions of the TPF.

The functions the TPF is intended to serve will, more than any other factor, determine the facility's design. In general, as the functions either increase or become diversified, cost and complexity of the facility go up. Thus it is important that the facility's functions, or

requirements, be established as early and as precisely as possible. At present, the TPF is meant to serve three prime functions. Other potential functions are considered and discussed in Section 3.

(1) Function 1. To Provide TSQ-47 Familiarization Training:

Training in the Air Force follows a careful stage-by-stage process which takes the trainee from a knowledge of general principles through to more specific applications of that knowledge. Air traffic controllers get their basic training in the Air Training Command. After 6 months of on-the-job training at a fixed site they become available for assignment to one of the Mobile Squadrons. Even though he is at the 5 skill level, the new controller arriving at the mobile squadron must perfect his overall controller skills, he must learn the unique characteristics of mobile operations, and he must acquire the particular knowledges and skills demanded by the special features of the TSQ-47. We have chosen to term this latter item TSQ-47 familiarization training. It will include learning such things as: the location of equipments that the operator already knows how to operate; the location and operation of unique equipments such as RACEP, the optical projectors, and the symbol tracking group; overall system deployment procedures; pre-deployment duties associated with teardown and return to squadron headquarters.

So far we have been talking about training a newcomer to the mobile squadron. When the TSQ-47 goes operational there will, of course, be the need to provide a comparable type of familiarization training to the personnel already in the squadron -- people trained in the use of the "4 Wheels" system. (Normally this type of training is referred to as transition training; for convenience we have included it under the title of familiarization training.) The nature of the training would be about the same as that mentioned above, but the amount required would be less. Thus, one of the TPF's prime functions would be that of familiarizing both newcomers and old hands at mobile operations with the equipment and operations of the RAPCON shelter.

Familiarization training of this type does not normally require a special training device. It is usually acquired directly on the job. By itself, therefore, this function does not justify a TPF. The facility is,

however, intended to serve other, more compelling functions. In doing this it also provides the opportunity for better familiarization training than is normally the case. It will do this by enabling such training to be better controlled, to actually precede operations rather than be conducted during operations, to be accomplished more rapidly, and to be better programmed and administered.

(2) Function 2. To Maintain Controller Proficiency
Between Deployments.

Mobile squadron operations are characterized by their intermittancy. When a mobile unit is needed it must be ready to go into service at peak efficiency. There is no time for people to "brush up" on their control procedures once they are in a disaster area charged with bringing in a flight of cargo aircraft or when there is a sudden conflict between two aircraft on final approach.

The period between deployments is when controller skills and knowledges are most apt to deteriorate and the TPF is intended to maintain operator proficiency during this interval.

(a) Length of Time between Deployments.

If steps are not taken to resist the very normal process of forgetting, then the loss of controller proficiency will be a function of how much time is spent between deployments. Informal estimates of this interval solicited from AFCS personnel varied from a few weeks to as much as a year or even more. Even when one allows for the subjective nature of such estimates it appears that very real performance losses could result. To better assess the magnitude of such losses it will be necessary first to get more reliable data on the mean inter-deployment interval for personnel of the three mobile squadrons and to get more information about the rate at which proficiency is lost.

(b) Trainee Performance Level.

Training and training devices to be effective must be adapted to the performance level of the student. For any given duty or

set of tasks the higher the proficiency level that is to be maintained the more refined the training must become. This usually demands more refined and complex training devices. For beginners who have literally "everything to learn," even the crudest training techniques and devices can be of service in acquiring rudimentary job knowledges and skills. But as skill increases, more and more refined training methods and devices are required to exercise and shape performance.

The training situation must always place demands on the trainee. It must provide an opportunity for performance to improve. The highly proficient controller may actually lose skill in a "training" situation which rewards performance that is below his proficiency level. He may in fact be learning to respond more slowly, to ignore certain types of errors or emergencies because the training situation does not include them, or, because of sluggishness in the way the equipment responds, he may be learning a different way of timing his responses. The mere fact that a trainee is using a training device is not proof that it is doing him any good.

The importance of these considerations for the TPF is obvious. If the facility is actually going to maintain controller proficiency it must be designed to meet the training requirements of even the most proficient controller. This will not prevent it from being used effectively for lower levels of training as well.

(c) Nature of the Controller's Task.

The controller's task is a composite of various skills and knowledges blended together in a complex and subtle manner. At the moment we do not know how these individual skills interact. It is for example, probable that they are learned and forgotten differentially. If these differences could be determined then training could emphasize those skills that are most easily lost or most difficult to acquire.

Naturally the instructor will be able to spot his trainees' weak points and adapt their training accordingly. But the training device he uses must be capable of supporting him. To make the TPF maximally effective detailed investigations will have to be undertaken to learn more about the composition of the RAPCON controllers' duties so that the TPF can be designed particularly to provide practice in the most critical of these duties.

(d) Individual vs. Crew Training.

In talking about controller skill and proficiency there is often the tendency to think in terms of a single operator. Such a view omits consideration of an extremely important part of the controller's task, namely, his duties as a member of a team. Not only must he work with other controllers in the RAPCON, but also with controllers in the TOWER in order for there to be complete coordination throughout the system. Some of the most critical incidents that we were told about in our talks with AFCS personnel were ones which could reasonably be attributed to a breakdown in controller coordination, especially between the RAPCON and the TOWER

The TPF will be suitable for the training of both individual controllers and teams of controllers. Thus intra-RAPCON team coordination training will be quite feasible. What may prove difficult is simulating coordination with Tower operations.

There is another aspect of the controller's job for which the TPF will be able to provide training. This is in operating across a number of positions as the controller is often called upon to do during quiet times. As a member of a full RAPCON team the controller will perform the tasks associated with a particular position. During periods of low traffic, however, he will be called upon to assume the responsibilities of perhaps three positions such as pickup, approach and feeder.

(3) Function 3. To Serve as a Pre-Deployment Trainer.

The third function envisioned for the TPF is for the pre-deployment training of controllers in local procedures and conditions at the deployment site.

Each airfield has its own peculiarities. The surrounding topography; the direction of the predominating winds; wind layering effects; major landmarks such as buildings, power lines, forests, etc., patterns of ground clutter; the direction and length of runways; locations of run-up areas, taxiways, hangers, access roads; the air routes over and adjacent to the field; navigational aids - all these things vary from one field to another. The proficient controller must "know" them for every facility in which he works because they enter in some measure into his decisions, communications and action.

Information concerning these "personality characteristics" of a particular airfield is acquired from charts and other sources. The TPS will provide the unique opportunity for controllers to use and get to think in terms of the peculiarities of a given deployment site even before they are sent there. Being informational and procedural in nature, this part of the controller's job is subject to rapid forgetting and interference from previously learned information. By exercising the controllers in the use of this information a good deal of the initial confusion associated with the deployment will have been removed in advance.

b. Trainee Population.

The current concept of the TPF calls for the training of the operators of the RAPCON shelter or AN/TSW-5. Fully manned, this involves 9 duty positions as follows: Pickup Controller, Approach Controller, Assistant Approach Controller, Feeder Controller, Precision Approach Controllers (2), Departure Controller, Assistant Departure Controller, and the Coordinator Supervisor who oversees all RAPCON operations. All of these positions fall within the broad outlines of the Air Traffic Control Operator specialty 272XO. The input level for the TSQ-47 will be the 5 level man (27250) and for the RAPCON most operators will be specialists in radar control of traffic. The supervisor will be at the 7 or 9 skill level and he will be qualified in both radar and nonradar control techniques.

c. Location of the TPF.

It is planned that TPF's will be located and used at the headquarters of each of the three mobile squadrons. Thus, training on the TPF would have to be restricted to the period between deployments. One of the implications of this plan is that the TPF can be designed specifically for training without having its prime functions compromised by requirements for mobility, all-weather operations, etc., as would be the case were the facility intended for field use. As a fixed facility the TPF can also be more elaborate since space, weight, spare parts and maintenance are not critical factors. Other advantages are gained in terms of ease of maintenance, regular programming of training sessions, etc.

There is, however, another implication to this arrangement which suggests a problem. The problem is, how will operator proficiency be maintained in the field? It is natural to place reliance upon on-the-job performance to do this, and deployments involving the control of moderate to heavy traffic loads spaced uniformly over time would justify such reliance since the regular practice would prevent any deterioration of operator skill. But consideration must also be given to other deployments - ones in which high traffic loads are experienced only sporadically; where the deployment stretches from 30 days to 90 or more and traffic is relatively light and undemanding most of the time; or the condition in which the weather is predominantly VFR and there is very little need to make use of the radar control equipment. Such deployments are more than merely possibilities. They occur, and they constitute occasions on which a good deal of skill and knowledge can and probably is lost. The degree to which one can rely on on-the-job performance to maintain operator proficiency depends upon just how much performance the job actually provides.

The TPF cannot solve this problem under the present conception, and it should not necessarily be expected to. The problem has been raised to show that the TPF is bound to have limitations and should not be viewed as the solution to all operator training problems in the TSQ-47 system. What is needed is an assessment of the magnitude of the problem. If it is eventually judged to be real then a solution must be found. This might very well involve specialized job aids or a training device for field use.

d. Equipment.

At present there are very few details regarding the equipment that is envisioned as making up the TPF. This is to be expected at this stage in the design process and, indeed, it is desirable since preconceived ideas about equipment all too often tend to dictate training functions rather than the reverse. And yet, it is virtually impossible to speak solely in terms of performance requirements without implying equipment of some kind.

A rather sophisticated simulator is envisioned which duplicates faithfully the internal appearance and equipment found in the TSW-5 shelter. All the radar indicators are meant to be operable in the shelter, though they will not be receiving signals directly from active radars. Instead,

signal generators will be used to simulate the performance characteristics of a wide variety of aircraft types. These signal generators will have to be "flown" by other controllers who are not undergoing training. The simulator "pilots" will communicate with the controllers in a realistic manner and then "fly" their "aircraft" according to the instructions they receive.

All positions in the RAPCON will be operable simultaneously, and the pattern of signals at all the scopes will depict a common aerial situation, making it possible to exercise an entire RAPCON crew at one time.

This concept of a highly realistic training situation follows from the following considerations:

- (1) Training is meant to maintain a proficiency level that is already quite high.
- (2) The controllers' task is a complex of interrelated knowledges and skills and we do not know how to parcel them out in terms of criticality or rate of forgetting.
- (3) Effective RAPCON operation involves that very subtle factor called "crew performance" which can only be achieved through the exercising of entire crews.

e. Summary.

As presently conceived, the TPF will be designed to (1) familiarize air traffic controllers with the equipment and operation of the TSQ-47, (2) maintain the proficiency of controllers between deployments, and (3) serve as a pre-deployment trainer. Intended for operators within the RAPCON shelter, the training is to be conducted at the mobile squadron headquarters. A fairly sophisticated facility is envisioned which would permit both individual and crew training.

SECTION 3

DESIGN CONSIDERATIONS

1. Scope.

In the last section the current status of the concept of the Training and Proficiency Facility was described and discussed. This section is intended to further explore the implications of that concept, to raise issues and questions which should be considered either as additions or modifications of the concept, and to identify important areas that the present concept does not include and which need to be considered before more detailed steps are taken toward actual design of the facility. Some of the considerations raised in this section can be resolved by a simple decision. They involve a question of what is wanted. Others cannot be resolved except by assumption or through the accumulation of empirical data, and expert opinion.

Design considerations to be treated in this section are:

- a. Additional Functions that the TPF may Serve.
- b. Use of the TPF for Performance Measurement.
- c. Use of an Operational vs. Simulated RAPCON
- d. Instructors and Instructor Aids.
- e. TPF Utilization

2. Additional Functions that the TPF May Serve.

In addition to the primary functions already established for the TPF, other functions are possible and should be considered. Some can easily be incorporated into the present concept since they will have little effect on the actual design of the facility. Nevertheless, they are worth making explicit. Other potential functions would affect the facility's design quite a bit; they need consideration and then it must be decided whether one or all are to become part of the TPF's requirements.

a. Cross Training for Tower Operators.

At the 3 and 5 level of skill the 272X0 specialty is divided into two groups - the "A" group is trained in nonradar control techniques, that is, visual control from a control tower; the "B" group is trained in radar traffic control (RAPCON) operations. Before controllers in either group can advance to the 7 or 9 skill levels they must be proficient in both types of control procedures. In the TSQ-47 there will be both kinds of controllers and the availability of the TPF will enable type A personnel to become cross trained in radar control techniques.

One can expect two important results from using the TPF in this way: (1) By adding radar control experience to the 5 level tower man, such cross training would hasten the up-grading process. (2) Cross training would improve overall system performance by increasing understanding and appreciation on the part of the nonradar types of the problems, information, needs etc., of the radar controllers. In operations, the two types of controllers work together very closely and such cross training would improve the integration of their respective tasks and responsibilities. At Scott AFB we were told about a number of "incidents" which could be attributed to a lack of coordination between the tower and the RAPCON, and which perhaps could have been avoided through more extensive cross training.

b. Develop and Test New ATC Procedures.

A sophisticated simulator always provides unique opportunities for uses other than training. Without modifying the presently conceived facility the TPF could be used to try out new control methods and techniques, new ways of patterning traffic or other procedures to see if they offer an improvement over standard techniques. Part of this function would involve the development of optimal emergency procedures. (Emergency operations are treated in more detail later.)

c. Test and Evaluate New Controller Aids.

Closely related to the function of evaluating procedures is one of evaluating special devices designed to assist the controller on his job.

A number of such devices are in existence and others will undoubtedly be developed to cope with the ever increasing complexities of air traffic control. The TPF would offer the very real possibility of testing and evaluating such devices to determine whether they improve system performance, how much, and in what respects. To do this well would require expanding the concept of the TPF to include the development of measurement equipment and techniques by which quantitative assessment of system performance could be made with and without the use of the proposed aids. Anything short of such a quantitative evaluation is usually inconclusive.

d. Training for Emergencies.

The TPF could be used to give controllers training and experience in handling emergencies - both those that are inherent in the nature of the air traffic control situation and those that accrue from the peculiarities of the TSQ-47 itself. True emergencies occur so seldom that the average operator is probably not able to handle them optimally. At present the best training for emergencies is many years of experience. A simulation facility could provide realistic training at an accelerated pace in the handling of emergencies such as the loss of ground equipment capabilities, failure of equipment within the aircraft, or marginal aircraft operation (low on fuel, loss of power etc.) and below minimum separation among aircraft.

Another use of the TPF along these lines would be to provide training in the use of the system under degraded conditions to simulate loss of equipment due to normal failures or as a result of direct enemy action. At such times it will be essential that the controllers be able to change their operating mode suddenly and efficiently. The facility could provide training in making the judgments required to shift rapidly from normal procedures to optimal emergency operations.

Though most emergencies could be reproduced by the careful programming of the aircraft simulators, some may require special instrumentation and design. These should be selected from a survey of potential emergencies using criteria such as frequency of occurrence, criticality, and cost of simulation.

3. Use of the TPF for Performance Measurement.

As now conceived the TPF is meant to fulfill its various functions by providing a situation in which fairly realistic practice of RAPCON operations can take place. It is intended to exercise controller performance, and reliance will be placed on traditional indicators to evaluate such things as:

- a. The effectiveness of the TPF.
- b. The relative level of controller proficiency within a unit.
- c. The effectiveness of new control procedures or controller aids.
- d. The operational readiness of the squadron.
- e. Whether a given controller's skill is improving.
- f. Whether a particular group of controllers is operating effectively as a team.

At present a variety of indicators exist which a commander or training officer uses to answer these questions. To illustrate the main ones let us consider how they may contribute to a commander's estimate of his unit's operational readiness.

(1) Experience level of the controllers.

In general, the more experience the men have the better prepared they should be to meet new situations. There are a number of ways to measure experience, but none of them tells directly what the men are capable of doing here and now. In other words, this indicator suffers from being too indirect. It tells a commander what his unit ought to be able to do not what it can do.

(2) Number of hazard notices received.

Hazard notices are indicators of system failures that have occurred. They are used on the basis that satisfactory past performance promises satisfactory future performance. Though there is truth in this generalization, one must be careful about how it is used. It must be remembered that hazard notices do not result from a systematic test of unit

proficiency. They are records - probably incomplete and inaccurate at times - of system failures whose occurrence required a very special set of circumstances in the ATC situation. Had these circumstances not occurred, there would have been no hazard, there would have been no hazard notice, and the unit's inability to cope with such situations would have gone undetected. The lack of hazard notices, instead of being proof of operational readiness, may reflect merely lack of hazardous situation. By the same token, existence of such notices cannot be taken as indicating widespread lack of proficiency. Hazard notices should best serve as warnings. They should be the occasion for investigation.

(3) Evaluations by instructors and staff personnel.

Here a person qualified, usually by virtue of his experience, makes a judgment concerning the trainee's or the system's readiness. Compared to the indicators already mentioned, performance ratings of this type offer an advantage in that they tend to be based on direct observations of individual and crew performance either on the job or in training. In addition, if the rater is good, they are likely to reflect the subtle nuances of performance which only "experience" can bring about. Their limitation lies in the fact that they are not specific, they are not quantitative, and they may be affected by the rater's own interests.

(4) Certification and rating test.

Such tests offer the most direct and objective indications of an individual's performance. The better people do on these tests the more prepared the unit is to carry out its mission. These tests are limited in that they tend to emphasize job knowledge rather than job performance - particularly crew performance.

From indications such as these the commander must judge whether his unit is in a state of operational readiness. The TPF can help him make this judgment and it can help to establish answers to the other questions posed at the beginning of this section. The advantages and disadvantages of three major design alternatives are discussed below. Again the discussion is in terms of estimating operational readiness.

(a) The TPF as an exerciser of performance.

As we have seen, such a conception of the TPF has little in it concerning performance measurement of any kind. In this alternative the TPF appears intended as a device which will provide task practice without special means of evaluating operator performance.

This design conception offers these advantages: It provides a highly realistic setting in which observations and ratings can be made. It permits the rater or instructor to "arrange" things so that he can observe particular performances. It makes it possible to increase the number of observations upon which the rater's evaluation is based. And it yields information and control over the type and amount of training being given to the unit.

This alternative's major disadvantage stems from its continued reliance upon subjective performance evaluations.

(b) The TPF as a performance measuring tool.

Special recording and measuring devices could be made part of the TPF in order to aid the instructor in assessing individual and crew performance. For example, at the end of a training session it might be possible to give the instructor a computed figure for the mean separation between aircraft on final approach.

There are a number of devices in the general category of controllers aids which could be used in this way. There are devices which can rapidly give the distance between two aircraft and determine if conflicts will occur. Also under development is a device which will project on a PPI a line representing a course for a minimum time to touchdown for any type aircraft from a distance of up to 90 miles from the runway. While the aircraft is still at the periphery of the control zone, it can be determined whether a safe separation between aircraft is likely to be maintained on final approach.

This design conception has these advantages: By providing quantitative information about selected aspects of controller and

system performance, it objectifies the instructors evaluations. It would improve the detection of changes in controller performance and so permit more rapid adaptation of training to the trainees needs.

The main disadvantages to this design alternative are that it will involve greater equipment cost and complexity, and that it will still be up to the instructor to decide how relevant the various measures are and to weigh them in arriving at an overall evaluation of individual and system performance.

(c) The TPF as a proficiency evaluator,

In the preceding design conception the TPF served to record and report selected aspects of performance. In this concept the TPF is used to "score" performance. What has been added is the evaluative function. In this conception the TPF is designed to answer such questions as: How proficient is a given controller? Or, how proficient is a given RAPCON crew? In previous design alternatives this was left to either the instructor or the commander.

For the TPF to perform this function it involves the difficult task of establishing performance criteria, and determining valid ways of combining these into hierarchies. Let us take as an example the problem of scoring a single individual on his skill as a controller. We recognize that a controller's proficiency depends on his ability to perform a variety of tasks. These must be defined. One very important one is that of communicating with aircraft. Under the preceding design alternative we would stop at this point, decide perhaps that the instructor will need a record of the controller's communication procedures, and require that the TPF include a tape recorder. Now, however, we must establish what it is that constitutes good communications procedures. Certainly speed, accuracy and clarity will be major factors. But how about timing, or that elusive quality of confidence and assurance that good controllers are said to convey?

From the factors identified as pertinent to communication procedures we must select the ones that we feel are important. (We would probably ignore mike handling ability.) When this has been done, performance criteria must be established to define how fast, how clearly, with what accuracy, etc., the controllers are expected to communicate.

Next, means must be found to actually measure communication rate, clarity and accuracy. This poses additional problems for the designer. Measuring the "time" of a response is fairly straightforward in most cases. But it takes ingenuity to measure the "timing" of a response.

Now measures must be combined. After all, what we want is a score of the controller's ability as a communicator, not a series of scores about his communications. Again, decisions must be made, and ingenuity exercised in finding ways of combining factor scores. One of the key questions involves how much emphasis or weight each factor is to be given. Is the formula for good communications procedures 2 parts speed, 1 part accuracy, and 1 part clarity? Or is it 5 parts speed, 4 parts accuracy, 3 parts clarity and 1 part each of timing and confidence?

When all this has been done, then a way has been found to score a controller's ability as a communicator. Then equipment must be designed to produce the score. And then the process is repeated for other tasks that are part of the controller's duties and which contribute to his overall skill.

By its explicit analysis of task structure, its objective measuring, and its systematic combinations of measures into scores, the process we have just described transfers the function of evaluating performance from the instructor to the training device. The advantage of this alternative is that it yields specific answers to the questions posed at the outset of this section. Also it permits a tracing of the "reasoning" behind a given score. By granting examination of the factors that contributed to a particular score, it serves a diagnostic function upon which "pinpoint" training can be based. The major disadvantage of this alternative lies, of course, in increased development time and costs.

4. Use of an Operational vs. Simulated RAPCON.

A major design consideration for the TPF is whether use should be made of operational or simulated equipment and to what extent. Each situation demands its own solution, but in general, operational equipment by virtue of having already been developed, offers the advantages of ready

availability, identical physical appearance, and lower cost (particularly where the system in question has been produced in large numbers). Operational equipment tends to have the following disadvantages: Since it has not been designed for training, it limits the training functions for which it can be used; whole portions of it - circuits and subassemblies - may not actually be required for the training situation and are therefore useless or perhaps even a hindrance to making the useable parts of the equipment available; it is often not rugged enough to withstand the constant use given to training equipment.

The TPF could be designed to make use of an operational TSW-5 shelter, but we feel that there are a number of reasons that argue against such an arrangement.

a. If the shelter were to serve both functions, then the wear and tear caused by using it as a trainer would reduce its usefulness for operations, and thereby reduce the mobile squadron's overall capability.

b. It may not be possible to set aside one RAPCON for training purposes alone. If all TSW-5's available to a given squadron were called into service, training would have to be suspended until one of the shelters returned from deployment. A good training program cannot operate on the basis of such contingencies.

c. A simulated RAPCON can be designed specifically for certain training functions. For example: special windows may be built into the walls for use by instructors or observers. The walls of the facility may be designed to swing away either for maintenance or to permit "live" demonstrations to new trainees or visitors to the facility; special mikes could be installed to monitor intercontroller communications; special recording and performance measuring equipment can be better integrated into the overall facility design.

5. Instructors and Instructor Aids.

The instructor is a very important part of almost all training situations - even those which employ teaching machines. He determines what the trainees need to learn, how they are to learn it, and when they have learned it. The instructor is usually himself highly proficient in the subject

of his instruction. However, this alone does not qualify him as an instructor. In addition to job knowledge and skill he must also possess teaching skills by which he continuously creates a learning situation. He does this with the help of books, blackboard, films, models, maps, mockups, teaching machines and simulators. Regardless of their complexity, these "things" of learning serve a common function - they aid the instructor in arranging the conditions under which learning of a particular skill or task or mission can take place.

Because of the dynamic nature of the ATC situation and because high levels of performance are to be maintained, the TPF promises to be a complex piece of equipment. To make full use of it will require instructors who understand its capacities and who know how to arrange and focus these on their trainees' needs. The ability of the instructors to program the TPF - that is to determine numbers of aircraft, arrival times, aircraft types, wind conditions and other variable parameters of the aerial situation - will in large measure determine the realism and effectiveness of the training exercise given. To provide such instructors, specific measures will have to be taken to select men and to train them in the use of the TPF.

Providing the trained instructors will be the responsibility of the using command. The equipment designer's responsibility will be to build the TPF in a way that maximizes the ease with which the instructor can use it.

Though it is not as serious a consideration, it is very likely that some training will also have to be provided for the personnel who fly the simulators.

6. TPF Utilization.

The TPF will be vastly different from the present T-2 trainer which two people can make use of virtually at a moment's notice. In the TPF a typical crew training exercise could involve 15 or more people (9 operators being trained, 1 instructor, 3-5 signal generator operators, and perhaps 1 or 2 maintenance men on a standby basis). Before the exercise can begin all will have to be present, the equipment may have to be warmed up, a briefing may be held, flight scripts will be passed out to the simulator "pilots," etc. The exercise may last from 2 to 4 hours. After it, a debriefing is likely to be held to evaluate overall team performance.

Again, as in the previous section on instructors, the using command and the equipment designer share the responsibility for making regular use of the TPF in this manner a reality. The using command must see to it that TPF utilization is part of a regular, well supported and well administered squadron training program. The designer must see to it that the facility can be rapidly readied for use, that it is reliable enough to prevent a full scale exercise from being interrupted by equipment failures, that target generators can be reset rapidly, and that the changeover from crew to individual training use is easily made.

SECTION 4

RECOMMENDATIONS

We have presented a conceptualization of a Training and Proficiency Facility for the TSQ-47 system and we have discussed a number of design considerations that may extend or modify it. In this section we recommend actions that we view as necessary in establishing detailed and valid performance requirements for the TPF.

1. It is recommended that the Air Force establish an updated set of requirements for the TPF. This report is intended to help make this feasible by structuring the TPF concept and pointing out major design considerations. As is usual, problems rather than solutions have been identified. These would not be resolved by an Air Force decision to say, "include among the TPF's functions training in emergency procedures." Such decisions would, however, make it possible for further study to be concentrated in areas of relevance to the TPF rather than being scattered across the far greater realm of "possible" functions.

2. It is recommended that further study be directed at determining the extent and nature of proficiency losses incurred between deployments.

As we have seen, the main function of the TPF is to maintain controller proficiency between deployments. And yet, we know very little about what constitutes controller proficiency or in what way and amounts it is lost. Until much more is known about these things an optimal facility cannot be designed.

3. It is recommended that a study be conducted to determine whether significant proficiency losses are incurred during deployments and to recommend a solution if one is necessary.

4. It is recommended that training in emergency procedures be included among the TPF's major functions and that a set of relevant emergency conditions be identified for simulation.

One of the truly unique functions that the TPF can serve is to provide controllers with practice in handling emergencies. It will not be practical or even desirable to simulate all possible emergencies. A sample

of representative emergencies needs to be identified for simulation. This sample should include emergencies produced by the complexities of the aerial situation, malfunctions of the TSQ-47 itself, and by faulty control procedures. Some may be simulated merely by careful programming of the signal generators. Others may require special instrumentation. Selection of emergency conditions should be made on the basis of their criticality, frequency of occurrence, and the complexities and costs of reproducing them in the TPF.

5. It is recommended that further study be made of the operations of all three mobile squadrons so that the TPF meets their needs and capacities.

The TPF is meant to be used in mobile squadron headquarters in Europe, the Far East, and the United States. In each location it will become part of an existing pattern of operational requirements and procedures, physical facilities, organizational traditions, policies and attitudes, maintenance and support capabilities, etc. These will largely determine how regularly the TPF is used, how well its capacities are exploited, the place where it is set up, how well it is maintained, and so on. In short, they will determine its effectiveness.

These "conditions" of utilization should enter into and affect the TPF's design - not as alternatives to or modifiers of its primary training functions, but as factors which influence how the prime functions are achieved. Because it is located in the United States the 3rd Mobile Squadron tends to be used as a model for all mobile operations. From what we can tell this is not justified since real differences exist between the operations, problems, length and types of deployments of the three squadrons. To make the TPF maximally useful to all three requires a much more representative picture of mobile operations than can be gained from studies of the 3rd alone.

6. It is recommended that the TPF be designed to include selected performance measuring capabilities and that further investigation be conducted into the question of using it as a proficiency evaluator.

Because various "controller aids" already exist, it seems worthwhile to design the TPF with them in mind. Recommendations for a proficiency evaluator should be based upon further study because too little is known about the feasibility, cost, and probable user acceptance of such a design concept.

7. It is recommended that the Air Force establish a utilization concept for the TPF and that plans be made for the training of instructor personnel.

8. It is recommended that a specific study be made of the instructors requirements for information displays, communications, special console requirements, recording devices, lesson plans, manuals etc.

9. It is recommended that the requirements for the number and performance characteristics of the signal generators be identified as soon as possible, and that investigations be conducted to determine the suitability of available signal generating equipment for use in the TPF.

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